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Capital Formation and Productivity Growth in South Korea and Taiwan: Realising the Catch-Up Potential in a World of Diminishing Returns

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Abstract

In this paper we reconstruct the non-residential capital stock of South Korea and Taiwan based on long-term series of investment in non-residential buildings and machinery and equipment. Secondly, we looked at the impact of capital input measures, using a stock as a well a flow measure of capital, on total factor productivity growth. Finally, to assess the potential for continued catch-up of the emerging economies towards productivity levels of the more advanced countries, we analyse capital-output ratios and the change in comparative levels of capital intensity and labour productivity.

For both countries we find a rapid growth of the capital stock for the total economy and for manufacturing, with growth rates that peaked between the mid-1960s and the mid-1980s. In particular with capital inputs measured in terms of service flows, total factor productivity growth is low up to the mid 1980s. Since then TFP growth slightly improved which is related to the slowdown of labour input growth. Capital-output ratios continued to rise for the total economy. For manufacturing we found a strong rise in capital-output ratios in particular since the 1980s.

In terms of comparative levels, there are still large gaps between the two East Asian countries and the USA in terms of capital-labour ratios and labour productivity. This indicates that despite the diminishing returns to capital goods, especially in manufacturing, opportunities for further growth on basis of accumulation are still far from exhausted. This remaining catch-up potential ought to be realised by complementing capital accumulation with productivity growth.

JEL codes: Macroeconomics, Growth and Fluctations (N1); Economic Development (O1); Technological Change (O3), Economic Growth and Aggregate Productivity (O4)

1. Introduction

Well before the start of the recent financial and economic crisis in Asia, a vigorous debate emerged about the factors behind the real growth performance of East and Southeast Asia since the 1960s and the barriers to further growth. Originally the debate revolved around the question whether the typical neo-classical factors, i.e. those that limit the role of governments and strengthen that of markets in reallocating resources to their most efficient use, or that interventionist measures, i.e. those that regulate financial markets and impose industrialisation policies, have explained the region's exceptional growth performance. In 1993 the World Bank further complicated the debate by introducing a "market friendly" approach as a way to blend aspects of the neo-classical and revisionist viewpoints (World Bank, 1993).

More recently the debate has become more focused around the question whether the accumulation of capital in Asia was so rapid that the growth process became typically extensive, and that future growth is likely to slow down because of diminishing returns to capital (Krugman, 1994). Indeed some scholars report rapid accumulation in combination with low total factor productivity growth in Asia (Kim and Lau, 1994; Young, 1992, 1994, 1995), but others emphasise that despite rapid accumulation TFP growth in East Asia has been quite respectable when compared to other developing regions in the world (Nehru and Dhareshwar, 1994; Sarel, 1995; Collins and Bosworth, 1996; Nadiri and Son, 1997; Timmer, 1999). In a recent paper, Easterly and Levine (1999) argue that it is TFP growth rather than capital accumulation which accounts for a substantial amount of cross-country differences in per capita income. Others again argue that the production function approach, which underlies this growth accounting work, is inappropriate as the distinction between capital accumulation and total factor productivity cannot be made and hides the fundamental driving factor behind growth, i.e. the search process to master new capital goods and substitute capital for labour (Nelson and Pack, 1999). Also, the recent literature on endogenous growth suggests that the returns on capital may be higher than assumed in the Solow production function because of spillovers. For example, the surge of foreign inflows of capital in emerging markets in the 1990s has rekindled new interest in foreign investment as a source of important spillovers to domestic capital (Balasubramanyam, Salisu and Sapsford, 1996; De Mello, 1997; Borenzstein et al, 1998).

Much of this debate has lacked clarity for several reasons, three of which are addressed in this paper. The first is related to the measurement of the domestic capital stock; the second to measuring the contribution of capital to total factor productivity growth; and the third to assessing the evidence on diminishing returns to capital in relation to the remaining catch-up potential for growth in the emerging economies.

Lack of reliable data in combination with the sensitivity of the procedures seriously limits the number of countries for which one can derive reliable estimates of the domestic capital stock (Nehru and Dhareshwar, 1993; Sarel, 1997). As a result many studies, in particular those that made use of cross-country regressions, have used investment-output ratios as a proxy for the change in the capital stock. This procedure assumes that marginal and average capital-output ratios are the same. A recent study by Fukuda and Toya has emphasised that this assumption is particularly unrealistic for East and Southeast Asian countries which are characterised by relatively low capital-output ratios in combination with high rates of capital accumulation (Fukuda and Toya, 1999).

Those scholars that constructed capital stock estimates reverted to different procedures. Essentially, two basic methods are available, namely wealth surveys which value the capital stock in place at user value, and estimates based on the perpetual inventory method (PIM) which are obtained by cumulating investment data using assumptions concerning the life time of assets and the depreciation pattern. The latter approach has been applied in two international datasets that aimed to include as many countries as possible, namely the World Bank dataset on physical capital (Nehru and Dhareshwar, 1993) and the Penn World Tables (Summers and Heston, 1991). The series from both datasets involve very substantial measurement problems, as the estimates are either based on indirect procedures, such as using investment/GDP ratios (Penn World Tables) or rough methods to derive a reliable benchmark estimates for the stock (World Bank dataset).[1]

Section 2 of this paper concentrates on capital stock estimates for two East Asian countries with extraordinary rapid economic growth over the past decades, namely the Republic of Korea and the Republic of China, Taiwan Area.[2] We review existing estimates based on wealth surveys and the perpetual inventory method, and we construct new PIM estimates for the total economy and manufacturing. Following Maddison (1995) we apply historical series for investment using assumptions concerning asset lives and depreciation patterns that are standardised across countries. In this way we arrive at an internationally consistent series of the capital stock for both countries beginning in the 1950s.

Section 3 of the paper analyses the measurement of capital input as a contributor to growth. The results from two alternative growth accounting procedures, one measuring aggregate capital input as a stock (stock-approach) and the other measuring capital service flows by weighting structures and machinery at their user cost of capital (flow-approach), are compared. We show that in periods with rapid change in the composition of the capital stock, the difference between the two methods can be substantial.

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[1] As this paper concentrates on two countries, we prefer to make use of methods that exploit the data to a greater extent and improve international comparability. Hence we refrain from using either the World Bank or Penn World Table data in the remainder of this paper.

[2] In the remainder of this paper we refer to these two countries as South Korea and Taiwan.

Section 4 relates changes in capital-output ratios to changes in the levels of capital-labour ratios (capital intensity) and output-labour ratios (labour productivity). This allows us to analyse both the development of the returns to capital and the remaining potential for a catch-up of capital intensity and labour productivity relative to the level of the United States, which is the productivity leader in the world economy.

The estimates in this paper will be for the total economy as well as for the manufacturing sector. The debate on the role of capital accumulation in growth often ignores the crucial differences concerning these relations at the sectoral level vis-à-vis the total economy level. In particular the manufacturing sector is likely to show different patterns, as the process of capital intensification was of greater importance than in other sectors of the economy.

2. Estimating the Non-residential Capital Stock

Because a world wide standardisation of the measurement of physical capital is still lacking, international comparisons of capital stock are fraught with problems.[3] Capital stock estimates are sometimes based on wealth surveys (see below), but more often on the perpetual inventory method (PIM).

The perpetual inventory method

The perpetual inventory method, which was pioneered by Goldsmith (1951), estimates the capital stock as the sum of past real investments which have survived up to the current period. This method requires assumptions with regard to service lives and retirement patterns of capital stock assets. In this paper we compile estimates of the gross fixed capital stock for the total economy and for manufacturing, assuming that assets are discarded in one stroke after their service lifetime. It is also assumed that repair and maintenance will keep the physical production capabilities of an asset constant during its lifetime. This is known as the one-hoss-shay efficiency pattern or rectangular retirement.[4] Hence the stock of asset type i at time t (K_{it}) is given by:

$$K_{it} = \sum_{t-d_i+1}^{t} I_{it} \tag{1}$$

with I_{it} investment at constant prices in asset type i at time t and d_i the service lifetime of asset i. Use of equation (1) gives gross fixed capital stock estimates which include depreciation as defined in the national accounts. Depreciation as reported by firms is largely determined by accounting and tax conventions and much less so by the actual decline in productive capacity

[3] In this paper we concentrate on the non-residential capital stock, i.e. non-residential buildings, and other construction (except land improvement), machinery and equipment and transport equipment.

[4] Different types of efficiency patterns such as geometric decline or straight-line depreciation are discussed for OECD countries by, among others, Ward (1976), Blades (1993) and O'Mahony (1996).

of the capital stock. Instead we assume that the productive capacity of each asset is constant until it is scrapped at the end of its lifetime.

An important problem in comparing perpetual inventory estimates of the capital stock across countries is that not only the depreciation patterns, but in particular the assumptions concerning the asset lives can differ substantially. For example, even within the OECD, asset lives for non-residential structures vary between 39 years in the United States, 57 years in Germany and 66 years in the United Kingdom (Maddison, 1995). Some of these differences may be 'true' differences as, among other reasons, an accelerated GDP growth can speed up the replacement of new for old assets. However, the observed differences cannot be directly related to this. Hence as a second-best approach (until internationally comparable asset lives are available) one might calculate the stock on the basis of standardised asset lives across countries. The standardisation method was pioneered by Maddison (1995) for total economy estimates for France, Germany, Japan, Netherlands, UK and the USA, and was replicated for manufacturing in Germany, Japan and USA by Van Ark and Pilat (1993) and for other sectors of the economy in France, Germany, Japan, the UK and the USA by O'Mahony (1996). Hofman (1998) applied the standardisation procedure to six Latin American countries.

Standardised capital stock estimates for South Korea and Taiwan

The capital stock estimates for South Korea and Taiwan in this paper are based on the standardised perpetual inventory method described above. Estimates for the total economy are provided from 1951 (Taiwan) or 1953 (South Korea) to 1995, and for manufacturing from 1960 to 1993. In general the method involves the following data requirements: gross investment series at current prices, price indices to revalue investment to constant base year replacement costs, asset service lifetimes or rates of actual depreciation, and a benchmark capital stock figure. The estimates and sources are presented in Appendix 1. Below we summarise the main elements of our procedures.

<u>South Korea, total economy</u>

For the period 1953-1995 two series on capital formation were obtained from the Korean national accounts, namely one for non-residential buildings and other construction (except land improvement) and one for transport equipment and machinery and equipment. For the period 1914-1938, we obtained total gross capital formation figures from Mizoguchi and Umemura (1988). To bridge the period 1938-1953, we estimated capital formation on the basis of output series assuming investment-output ratios at 0.10 for the period 1939-1944, at 0.00 for 1945 and 1946, at 0.05 for 1947-1950 and at 0.00 for 1951 and 1952. After linking, the investment series was expressed in 1990 Won. As the pre-1953 figures were not divided into series for non-residential structures and machinery and equipment, we roughly estimated these shares on the basis of the Japanese investment figures (from Maddison, 1995) which we lagged about 20 years: this implied that we assumed that the share for non-residential structures fell from 65 per cent between 1914 and 1920, to 60 per cent between 1921 and 1930 and 55 per cent between 1931 and 1952. Next we applied the perpetual inventory method, by using the standardised asset lives of 39 years for structures and 14 years for equipment from Maddison (1995). Moreover we discounted all pre-1953 investment by 40 per cent to account for war damage (Maddison, 1998, Table 3.10, p. 66). The first cumulated benchmark estimate is provided for 1953. The estimates are adjusted from end-year to mid-year basis.

Taiwan, total economy

The procedure for the estimation of the capital stock of the Taiwanese economy was similar to that used for South Korea. For the period 1951-1995 two series on capital formation were obtained from the Directorate-General of Budget, Accounting and Statistics (DGAS) for non-residential structures and for plant and equipment. For the period 1912-1938, we obtained total gross capital formation figures from Mizoguchi (1997). To bridge the period 1938-1951, we estimated capital formation on the basis of output series assuming investment-output ratios at 0.10 for the period 1939-1944, at 0.00 for 1945 and 1946 and at 0.05 for 1947-1950. After linking, the whole investment series was expressed in 1991 Taiwanese dollars. As the pre-1951 figures were not divided into series for non-residential structures and machinery and equipment, we used the same share estimates as for the Korean investment figures (see above). Next we applied the perpetual inventory method, by using the standardised asset lives of 39 years for structures and 14 years for equipment from Maddison (1995). We also discounted all pre-1947 investment by 40 per cent for war damage (Maddison, 1998, Table 3.10, p. 66). The first cumulated benchmark estimate could be provided for 1951. The estimates were adjusted from end-year to mid-year basis.

South Korea and Taiwan, manufacturing

For manufacturing only one series for total capital formation (but excluding residential structures) could be obtained from the national accounts. To obtain an average standardised asset life for the whole investment series, we used the average asset lives for a number of OECD countries from van Ark and Pilat (1993, p.42), namely 45 years for investment in non-residential structures and 17 years for investment in equipment and vehicles. These asset life estimates were then weighted by the share in gross fixed capital formation for Taiwan in 1987, which provided an average lifetime of 25 years.[5] Investment series for manufacturing go back to 1953 for South Korea and 1951 for Taiwan. We obtained investment series for the pre-1953 (Korea) and pre-1951 (Taiwan) period using the trend in capital formation for the total economy in both countries together with the 40 per cent-war damage adjustment.[6]

The Sensitivity of the Capital Stock Estimates

Clearly the standardisation procedure may be sensitive for the various assumptions involved. In particular the assumptions concerning asset life times may affect the results. For example, one

[5] The share in gross fixed capital formation in Taiwanese manufacturing is 31 per cent for structures and 69 per cent for equipment in 1987 (MOEA (1987) *Annual Report on the Corporated Enterprises Survey, Taiwan Area, ROC*, No. 19, Table 2-4).

[6] This procedure slightly differs from that used in Timmer (1999) where the pre-1953 & 1951 series were derived from the average growth rates from 1951 to 1956 (for Taiwan) and 1953 to 1957 (for South Korea).

might argue that asset lifetimes in rapidly growing Asian countries are likely to be shorter than those in more slowly growing OECD economies because of higher investment rates and a more rapid turnover of firms due to the continuing process of introducing new technologies from more advanced countries (industrial upgrading).

To test this proposition we recalculated the standardised estimates for the total economy and manufacturing in South Korea and Taiwan using alternative asset life assumptions.[7]

Table 1: Capital stock estimates using alternative lifetimes, total economy and manufacturing, 1987 (as per cent of preferred estimate)

	Alternative lifetime assumptions				
Total Economy	18+5 years	22+6 years	30+10 years	39+14 years	45+19 years(a)
South Korea	73	79	94	100	104
Taiwan	65	72	89	100	107
Manufacturing	10 years	15 years	20 years	25 years	30 years
South Korea	77	92	97	100	101
Taiwan	64	86	96	100	101

(a) for Korea: 42 years for non-residential structure and 19 years for plant and equipment.
Source: PIM estimates with rectangular retirement patterns, war-damage adjustment (for total economy) and alternative lifetimes for total non-residential fixed capital using investment series from Appendix 1, compared with the preferred estimates discussed in main text.

The overall conclusion from the table is that small variations in lifetimes have a limited impact on the capital-stock estimates for the Asian countries. If the assumed asset lifetime for South Korea and Taiwan is reduced to 30 years for structures and 10 years for plant and equipment, the total economy stock in 1987 declines with 6 and 11 per cent respectively. The effects for manufacturing are even smaller because the faster growth of investment compared to the total economy reduces the impact of changes in asset lives. Further study on international differences in asset lifetimes is called for, but in the remainder of this paper we use our preferred estimates.

Comparison of the Results with Previous Estimates

For both South Korea and Taiwan capital stock estimates exist, based on a mix of national wealth surveys and the perpetual inventory method. In a series of papers, Pyo (1988, 1992, 1998) provides estimates of gross fixed capital stock in South Korea based on wealth surveys in 1968, 1977 and 1987, linked with investment from the national accounts. For linking between benchmark years Pyo uses the polynomial-benchmark method. For the period before the first and after the last benchmark year a perpetual inventory method is applied as described above. Pyo's method assumes that the benchmark estimates from the wealth surveys are the best available estimates. An important advantage of this method is that

[7] Variations in retirement patterns have only small effects. Similarly, variations in initial year estimates have also little influence as by far the biggest part of investment in these dynamic economies has been made in the last decades. See O'Mahony (1996) for a sensitivity analysis on capital stock estimates for OECD countries.

depreciation of the assets can be directly calculated from the model.[8] In his earlier work Pyo estimated gross and net capital stocks independently. In his latest study he first estimates net capital stocks, which are converted to gross stocks using interpolated net-gross conversion ratios from the wealth surveys (Pyo, 1998). This revision leads to a downward adjustment of the results, especially before 1968. Kim and Hong (1997) also base their estimates on wealth survey data, but use only the survey of 1987 as they consider that one to be more reliable than the earlier surveys.[9]

Official capital stock estimates for Taiwanese manufacturing are provided by the Directorate General of Budget, Accounting and Statistics (DGBAS), which uses the benchmark extrapolation method (DGBAS 1994). However, the series are not fully comparable as capital formation in agriculture is excluded in the estimates by DGBAS.[10] Liang and Jorgenson (1995) used a similar method for calculating the stock of various asset types as they "adjust the time series data of capital stock by employing the National Wealth Censor (1988)".

Tables 2 and 3 compares the value of the capital stock according to our standardised estimates derived from the perpetual inventory method with those from Pyo and DGBAS respectively. In all cases our estimates are lower than the estimates based on the wealth surveys. The gap in the early years is particularly large for Taiwan, and especially for manufacturing. However, the gap between the DGBAS estimates and our figures becomes much smaller over time, which implies that our estimates show more rapid capital accumulation than the wealth based estimates. For South Korea, the gap between Pyo's and our estimates is slightly increasing over time.

Both because of reporting errors and theoretical differences, the PIM estimates will inevitably differ from the wealth survey results. There are two main limitations of the PIM method (Pyo, 1998). The first is the need for long historical investment series. In this paper, we show that this limitation can be overcome using historical national accounts studies. A second limitation is the need to assume particular asset lifetimes. Lifetimes may differ across countries and over time, and further research is needed here. By using standardised asset lives as in this paper, international comparability is enhanced. The estimation procedure is transparent and it is possible to check the sensitivity of the results. Although wealth surveys have the advantage that they measure the assets actual in use, when extrapolating the benchmark stock to obtain a time series assumptions concerning retirements have to be made

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[8] See Pyo (1988) for a discussion of the methods.

[9] Pyo (1998) provides a comparison of his old and new estimates in Table 12. Note that the pre-1977 figures given in this table for Pyo (1992) are based on erroneously aggregated figures in the original publication (see Pyo 1992, Table A2). He also shows that the results of Kim and Hong (1997) lead to very high estimates of the capital stock in the 1960s and 1970s. In 1962, their estimate of the gross stock is 3.5 times higher than his and five times higher than our estimate. See Table 2.

[10] It is not clear whether residential buildings are included in the DGBAS estimates. As they are based on a wealth survey amongst firms, probably part of the residential buildings stock will be included.

as well. The actual nature of the survey is crucial for its usefulness for capital stock measurement (Ward, 1976). Ideally, the survey should be a survey of physical assets on a case by case basis and it should have a complete coverage, but such surveys are complicated and prone to measurement errors. If instead the survey is based on book values, as often reported in censuses, its use is much more circumspect. Balance sheets valuations reflect a cumulation of historical prices of different time periods, they depend on the depreciation accounting practices of firms which are mainly influenced by tax conventions rather than the actual decline in productive capacity, and the vintage composition of the stock is unknown. Even though the Korean wealth survey comes close to a survey of physical assets (Pyo 1998, p.19), the official Taiwanese capital stock figures seem to be based on balance sheets.[11] Another important shortcoming of using wealth surveys is the problem of obtaining consistent methods of evaluation both across countries and over time (Ward, 1976). Therefore we prefer to use our internationally consistent estimates based on the PIM method.[12]

Table 2: Capital Stock in South Korea according to this Study and Pyo (1998) Total Economy and Manufacturing, 1953-1996

	Total Economy			Manufacturing		
	This Study	Pyo (1998)	This study/ Pyo (1998)	This Study	Pyo (1998)	This study/ Pyo (1998)
	bln. 1990 Won		(%)	bln. 1990 Won		(%)
1953	9,502	11,241	0.85			
1963	13,263	19,518	0.68	3,006	3,848	0.78
1973	46,205	55,256	0.84	9,991	14,673	0.68
1985	224,494	297,191	0.76	62,985	102,137	0.62
1996	736,682	980,149	0.75	262,177	404,847	0.65
	annual compound growth rate (%)			annual compound growth rate (%)		
1953-63	3.3	5.5				
1963-73	12.5	10.4		12.0	13.4	
1973-85	13.2	14.0		15.3	16.2	
1985-96	9.1	9.2		11.0	12.5	

Note: all growth rates in this paper are exponential rates.
Source: South Korea PIM based on investment series in *National Accounts* and (for total economy) from Mizoguchi and Umemura (1988), with assumptions as explained in text. Survey estimate taken from Pyo (1998), Table A4.

[11] Comparison with the Taiwanese production census data suggests that the census is used as a benchmark. According to DGBAS, *Report on the Industrial and Commercial Census in Taiwan-Fukien district of the ROC 1991*, Table 10, the total gross value of fixed assets in the manufacturing sector in use in 1991, excluding land, was 3,544 billion NT$ (in 1986 prices) which is almost identical to the 3,537 billion NT$ given in DGBAS (1994).

[12] All growth rates in this paper are exponential rates.

Table 3: Capital Stock in Taiwan according to this Study and DGBAS (1994)
Total Economy and Manufacturing, 1951-1996

	Total Economy			Manufacturing		
	This Study	DGBAS (1994)	This study/ DGBAS	This Study	DGBAS (1994)	This study/ DGBAS
	bln. 1991 Taiw. $		(%)	bln. 1991 Taiw. $		(%)
1951	175,984					
1963	381,578	587,740	0.65	77,514	276,421	0.28
1973	1,342,357	1,515,804	0.89	452,605	701,416	0.65
1985	5,305,229	5,666,234	0.94	1,881,825	2,157,588	0.87
1996	13,290,618			4,759,042		
	annual compound growth rate (%)			annual compound growth rate (%)		
1951-63	6.4					
1963-73	10.5	7.9		17.6	9.3	
1973-85	11.5	11.0		11.9	9.4	
1985-96	7.7			7.1		

Note: DGBAS (1994) excludes capital in the agricultural sector of the economy.
Source: Taiwanese PIM based on investment series in DGBAS, *National Income in Taiwan Area*, and (for total economy) from Mizoguchi (1997), with assumptions as explained in text. Survey estimate taken from DGBAS (1994).

3. Capital Stock, Capital Services and Growth Accounting

The capital stock estimates presented in the previous section can be used in a growth accounting exercise as introduced by Solow (1957) and developed further, along somewhat different lines, by Denison (1967) and Jorgenson and Griliches (1967). Growth accounting decomposes the growth of output (Y) into the contributions of the growth of inputs (X = labour, capital, etc.) and a residual, which may be called total factor productivity (TFP) growth. This residual can be defined as the difference between output and a weighted average of input growth according to the following formula:

$$\ln\frac{A_{t+1}}{A_t} = \ln\frac{Y_{t+1}}{Y_t} - \sum_j w^j \ln\frac{X_{t+1}^j}{X_t^j} \qquad (2)$$

with w^j the weight of input j. Here we consider only labour and capital input.

The contribution of capital input to growth can be measured by the growth of the aggregate capital stock, as obtained in the previous section, weighted at the share of capital income in total output . However, by disaggregating the capital stock into various assets and weighting those at the user cost of capital, one obtains the flow of capital services from the installed capital stock. This flow approach takes account of the differences in capital services delivered by the various types of capital assets (Jorgenson and Griliches, 1967). A dollar invested in buildings will yield a lower annual revenue product than a dollar invested in machinery. Typically, the share of machinery in the capital stock increases over time, especially during a period of rapid industrialisation. Consequently, TFP growth rates will be lower on the basis of the disaggregated flow approach to capital measurement using service flows than on the basis of the aggregated stock approach.

In obtained capital service flows, we follow Jorgenson, Gollop and Fraumeni (1987) and assume that the growth of aggregate capital input (K^T) is given by a weighted growth of individual capital inputs ($K^T{}_k$) using a Tornqvist index where weights are given by the shares of each asset type in the total value of property compensation

$$\ln K^T - \ln K^{T-1} = \sum_k \bar{v}_k [\ln K_k^T - \ln K_k^{T-1}] \tag{3}$$

with $\bar{v}_k = \frac{1}{2}[v_k^T + v_k^{T-1}]$ and $\bar{v}_k^T = \frac{p_k^T K_k^T}{\sum_k p_k^T K_k^T}$ with p_k the rental price of asset type k.

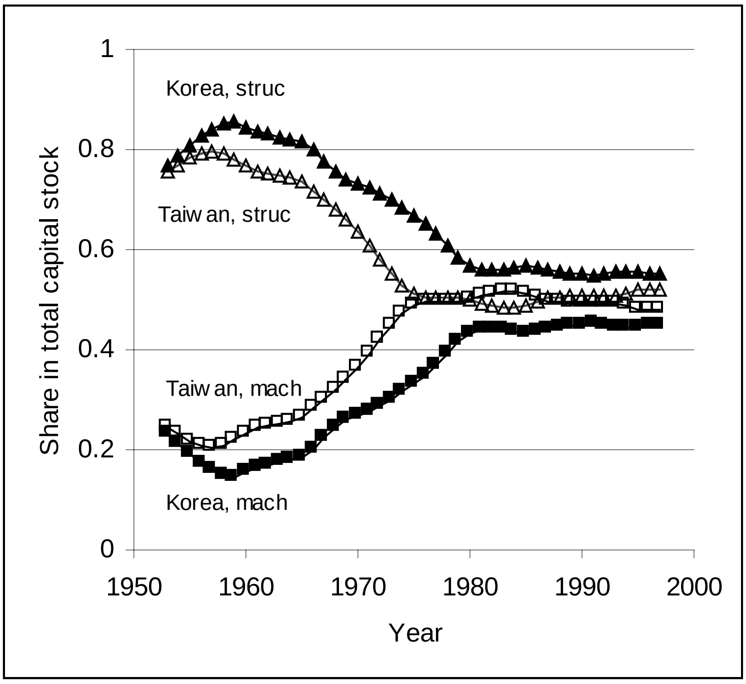
The rental prices of the different asset types are difficult to observe in practice and need to be estimated. Three approaches can be distinguished with an increasing degree of sophistication. The simplist way to estimate the user cost of capital (i.e., the rental price of capital services divided by the acquisition price) is by the depreciation rate (Ward, 1976, used in Timmer, 1999). This captures the idea that longer lived assets provide less services per year. More sophisticated is the opportunity-cost approach in which the cost of capital is approximated by a standard cost-of-capital formulation as follows (O'Mahony, 1999):

$$\frac{p_k}{P_k} = i + \partial_k - (\Delta P_k - \Delta P) \tag{4}$$

with i the real interest rate, δ_k the depreciation rate, P_k the purchase price of asset type k and P the average purchase price of all assets. The last term is included to represent capital gains. The most elegant is the residual approach used in Jorgenson, Gollop and Fraumeni (1987) in which national accounts data on property compensation is used to estimate rental prices internally. The value of the marginal product of aggregate capital is equated with realised profits. The rate of return is estimated using the national accounting identity between total value of capital services (rental price times asset quantity) and total property compensation. When industry level data is available, this method allows for varying rates of returns across industries. In their estimation Jorgenson and associates also take into account differences in tax rates. The residual approach has been used by Liang and Jorgenson (1995) in their study of Taiwanese growth, but as it puts high demands on data, it is not attempted in this multi-country study. Instead, we apply the opportunity-cost approach. The main problem with the opportunity-cost approach is to pick an appropriate real interest rate. Following O'Mahony we set this figure uniformly at 5 per cent for both South Korea and Taiwan.[13]

From formula (3) it can inferred that if the stock of the various capital assets grow at similar rates, the aggregate capital service flows will grow at the same rate as the aggregate capital stock. Hence, the two approaches will only generate different results in the case of a change in the asset composition of the aggregate capital stock. Figure 1 shows the compositional change in the aggregate capital stock for these two asset types, as obtained from the previous section.

Figure 1 Share of Non-Residential Structures and Machinery in Total Fixed Non-Residential Capital Stock, South Korea and Taiwan, 1953-1997 (share in total stock)



Source: Appendix Table I

It follows from Figure 1 that both in South Korea and Taiwan the asset composition of the capital stock changed rapidly between 1950 and the mid 1970s. After an initial decrease in the 1950s, the share of machinery gradually increased in the 1960s and 1970s from about 20 per cent to 50 per cent of the total non-residential fixed capital stock. Afterwards the share remained stable. The use of the capital service approach will therefore be particularly important for capital input estimates in the early period. Because of a higher depreciation rate, machinery generally has a higher rental price than buildings, and hence capital service flows will grow faster than the aggregate capital stock in this period. This is confirmed by the results presented in the first two columns of Table 4. The first column presents the growth

[13] Negative rental prices arise when asset deflators are highly volatile. In such a case one can smooth the price deflators over a number of years. We did this only for the case of Korea in 1961. In a next version of the paper we will use more realistic estimates of the real interest rate, e.g. by using the deflated corporate bond rate, but it has been shown that the results are not very sensitive to this choice. See Oulton and O'Mahony (1994), Appendix G, for a discussion.

rates according to the stock method and the second the growth rates based on the flow method using the opportunity-cost approach to obtain rental prices. In both countries, capital input growth using the latter method is higher, especially for the period 1963-73 in Taiwan, and 1973-1985 in Korea.

To indicate the importance of this difference in capital input measurement for TFP growth calculations, we present growth accounting results using both alternative capital input series in Table 4. To maintain consistency between our estimation of capital input with that of labour input, we adjusted the total number of working hours for labour quality. A labour quality index, measuring educational attainments, was obtained from Lee and Kim (1997) for Korea, and a similar index was constructed for Taiwan. For the weighting of the input series we applied a variant of formula (2), which applies the average weights of the current and previous years according to the following translog formula (Jorgenson, Gollop and Fraumeni, 1987):

$$\ln \frac{A_{t+1}}{A_t} = \ln \frac{Y_{t+1}}{Y_t} - \sum_j \bar{v}^j_{t+1} \ln \frac{X^j_{t+1}}{X^j_t} \tag{4}$$

with $\bar{v}^j_{t+1} = 1/2\,(v^j_t + v^j_{t+1})$ and v^j_t the value share of input j in output at t. Here we consider only labour and capital input.

Table 4: Alternative Capital Input Series and Their Effect on Total Factor Productivity (TFP) Growth (average annual growth rates, %)

	GDP	Labour input (b)	Capital input based on aggregate stock	Capital input based on service flows (a)	Capital share in value added	TFP using capital stock	TFP using capital services
South Korea							
1963-73	8.62	5.63	12.48	13.31	0.44	0.05	-0.32
1973-85	7.53	3.65	13.17	14.44	0.39	0.17	-0.35
1985-96	8.25	3.28	10.80	10.96	0.36	2.27	2.21
1963-96	8.10	4.13	12.17	12.94	0.39	0.83	0.51
Taiwan							
1963-73	10.57	4.09	12.58	14.55	0.51	2.14	1.13
1973-85	7.65	2.95	11.45	11.88	0.51	0.38	0.16
1985-96	7.06	1.97	8.35	8.19	0.50	1.91	1.99
1963-96	8.34	2.97	10.76	11.46	0.51	1.42	1.07

Notes: (a) capital services based on changes in stock of two asset types: non-residential buildings and machinery. See main text for methodology.

(b) Labour input is based on hours worked, corrected for changes in labour quality based on changes in educational attainment using the same method as for capital input as described in main text. Labour quality index for Korea was taken from Lee and Kim (1997, Appendix I, series I). Labour quality index for Taiwan was calculated by authors using same methodology and data from DGBAS, *Yearbook of Manpower Survey Statistics, 1993*, Table 11 for 1978-1993 and from DGBAS, *Social Indicators in Taiwan Area, 1993,* Table 29 for 1963-1977. Quality change for 1993-97 based on average change during 1988-1993.

Sources: Employment and working hours from GGDC Total Economy Database. Capital stock and capital services from Appendix 1. Capital share in value added for Korea from Pilat (1994, Annex Table I.7) assuming no change after 1990. Capital share in value added for Taiwan from DGBAS (1994, Table 7) assuming no change before 1978 and after 1993.

The results are shown in the last two columns of Table 4. Obviously, TFP growth rates are lower when using the faster growing capital service input series. During the period 1963-73, TFP growth in Taiwan is estimated 1.0 percentage point lower when using capital service input. For Korea, the small TFP growth rates for the period up to 1985 when using the stock approach turn into negative TFP growth rates when using service flows. For the more recent period the differences in TFP growth rates using either the stock or the flow estimates are much smaller as the stocks of buildings and machinery tend to grow at the same pace. But whatever measure is adopted it is clear that the TFP growth rate was increased since the mid 1980s compared to the earlier period.

Our results for Korea differ from previous growth accounting results as presented in Kim and Hong (1997) and Pilat (1993). Both studies show much faster growth in TFP in the 1960s and 1970s. This is mainly explained by the difference in the growth rate of capital. Both use capital stock data based on wealth surveys, and in addition they apply the stock approach to calculate capital input growth. As discussed above, our capital input series which are based on the PIM-method and use the flow-approach, show much faster growth and hence we find lower TFP growth rates. Young (1995) uses a similar approach as ours, but he excludes the agricultural sector from his analysis. His results for Korea and Taiwan are comparable to ours as TFP growth clearly show an improvement in the 1980s compared to the 1970s. A similar improvement in TFP growth for Taiwan is found by Liang and Jorgenson (1995, Table 8) who take the gross-output approach to growth accounting and also account for changes in the use of intermediate and energy inputs, apart from factor inputs.

It should be emphasized that the TFP calculations in this section are not meant to provide an estimate of technological change. It is clear from the literature that technological change is at least partly embodied in the inputs. In its most extreme form all technological change, as far as it is captured by the investors in their returns, is embodied in the inputs. The TFP residual then solely represents non-pecuniary spillovers (Jorgenson, 1995). Others, like Denison (1967), would argue that after accounting for various residual factors, such as improved resource allocation, economies of scale, etc., the final residual may represent advances in knowledge, as a form of disembodied technological change.[14]

Abramovitz (1979) recognizes the importance of a catch-up potential in the residual which can be realised through benefitting from the diffusion of technological and organisational knowledge. Given what was said above, one must distinguish between two ways in which potential for catch-up growth can be realized. One is through investment opportunities, that is the realizing the potential for further investments, given the gap in capital intensity relative to

[14] See also studies of this nature for Korea, in particular Kim and Park (1985), Pilat (1994) and Kim and Hong (1997)

the leading countries in the world. Another potential is found in closing the gap in (total factor) productivity levels compared to the world technology leaders. This productivity gap indicates the gains which can be made through further diffusion of (disembodied) technology from the global frontier. In reality these two vehicles through which the catch-up potential is realized strongly interact (Abramovitz, 1986, Ohkawa, 1993). But what is crucial here is that in both cases we need to look not only at growth rates but also at levels in an internationally comparative perspective. In the following section we will therefore look at capital-output ratios converted at international prices, and at comparative levels of capital intensity and labour productivity.

4. Diminishing Returns and Catch-Up Potential

This section looks at the pace of capital accumulation in relation to the change in labour input and output.[15] We first focus on changes in the capital-output ratios to analyse the issue of diminishing returns to investment. Next, the issue is treated more in depth by relating capital intensity and labour productivity trends and levels. The "catch-up" perspective is provided by comparing developments in South Korea and Taiwan with those in the USA.

Diminishing returns to investment?

As discussed in the introduction to this paper it has been suggested by various authors that in recent decades capital accumulation in East Asia has been so rapid that decreasing returns are likely to set in. To test this claim we provide comparative trends in capital-output ratios in international prices. Output and capital stock were converted to US dollars (prices of 1990) on the basis of purchasing power parities for GDP and capital formation respectively.[16] Figure 2 shows the changes in the capital-output ratio in the total economy. In the 1960s, South Korea and Taiwan were characterised by particularly low capital-output levels compared to the USA as stressed by Fukuda and Toya (1998). This indicates that capital was used in a highly productive way. As the investment process accelerated in the following decades, the capital-output ratio slowly converged towards the level of the USA. This reflects a change in the economic structure towards more capital intensive production processes as is to be expected during an industrialization phase. In 1995, the amount of capital used per unit of output is still considerably lower in the East Asian countries than in the USA.

[15] Hence we refrain here from making further observations on the basis of total factor productivity, because many of the differences in results depend on the growth accounting methodology adopted, as described above.

[16] GDP for the total economy was converted to 1990 US$ with "Geary-Khamis"-type purchasing power parities which were obtained from Maddison (1995) for Korea (updated from 1980) and from Penn World Tables (version 5.6; described in Summers and Heston, 1988) for Taiwan. For manufacturing GDP we used binary PPPs based on unit value ratios from Pilat (1994) for South Korea and Timmer (1999) for Taiwan. Capital stock was converted into 1990 US$ by using investment PPPs for 1990 for Korea and Taiwan divided by the investment PPP for the USA from PWT 5.6. Hence the capital stocks are all expressed at the same investment price.

The relative changes in the capital-output ratio in manufacturing are rather different as shown in Figure 3. In the early phase of industrialisation in the 1960s, capital-output ratios were already high and comparable to those in the USA.[17] This contradicts the suggestion by Fukuda and Toya (1998) that the low capital-output ratios at the total economy level in East Asia are mainly due to low levels in manufacturing. On the contrary, it appears that low capital-output ratios in the non-manufacturing sectors must account for the lower total economy levels relative to the USA.

When comparing the relative trends between the total economy and manufacturing, it should be noted that all figures are converted to 1990 US dollars using PPPs. It is a stylised fact that relative price levels of developing countries relative to the USA (or any other advanced country) are higher in manufacturing than in non-manufacturing. Indeed, in 1987 the relative price level (i.e. the purchasing power parity relative to the exchange rate) of South Korea vis-à-vis the United States was 85 per cent for manufacturing output but only 58 per cent for the total economy. For Taiwan the difference was smaller, i.e. a relative price level of 78 per cent for manufacturing versus 61 per cent for the total economy (Timmer, 1999). Hence in domestic prices the difference between capital-output ratios in the total economy and manufacturing would be less, but still significant.

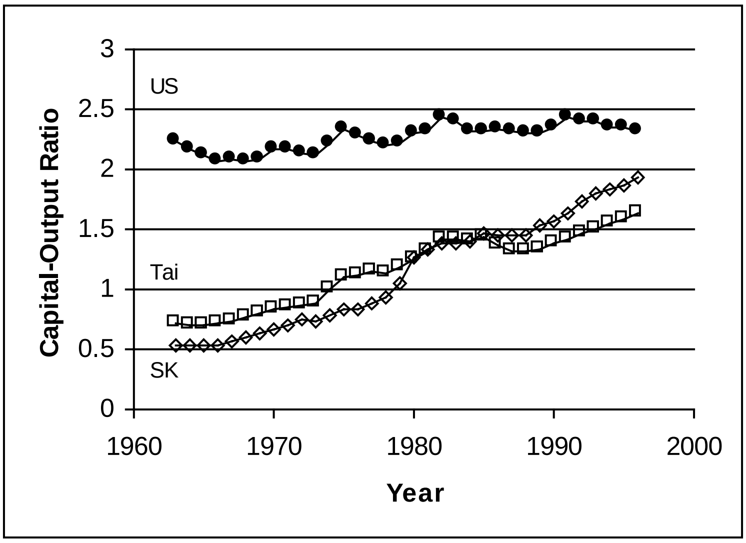
A particular interesting feature of Figure 3 is the development of the capital-output ratio in South Korean manufacturing which first declined from a very high level in the 1960s, reached a low in the 1970s and increased afterwards, especially since the end of the 1980s. In Taiwanese manufacturing the ratio steadily increased since the beginning of the 1960s with a similar acceleration as South Korea during the 1980s. The difference between South Korea and Taiwan in the 1960s is a reflection of the different industrial development paths. In both countries investments were geared into labour-intensive exports, but at the same time secondary import substitution and the establishment of heavy industries such as oil refining and basic metals was pushed much more in South Korea than in Taiwan (Amsden, 1989; Timmer, 1999).

The rapid increase in the capital-output ratio since the late 1980s in both countries suggests that capital in the manufacturing sector has been accumulated at increasingly faster rates with little additional output growth. In 1995, the ratio is higher than in the USA in both countries. This observation lends partial support to Krugman (1994) and Young (1995) who argue that diminishing returns to capital will reduce further growth prospects in East Asia. Still, from the beginning of the 1980s onwards, the manufacturing sector in South Korea and especially in Taiwan underwent radical structural changes. Rising wages and increased competition from other Asian low-cost producers caused the competitiveness in the labour-intensive industries such as textiles and wearing apparel to dwindle rapidly. As a result, manufacturing activities were quickly upgraded. TFP growth rates even improved mainly

[17] When using the estimates by Pyo (1998), the ratio in South Korea would be even higher. This provides further evidence in favour of our PIM-estimates.

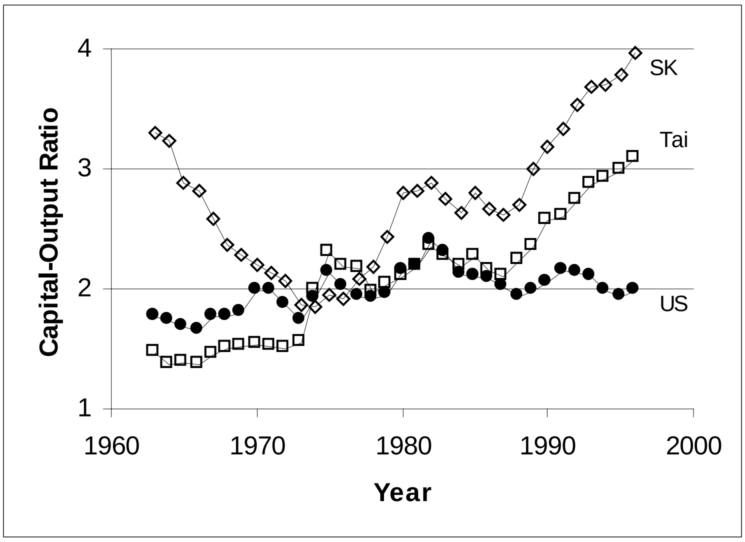
because of the slowdown in labour input growth. However, the rising capital-output ratios suggest that this process of industrial upgrading did not translate into higher output growth rates. On the contrary, as the capital intensification of the production process proceeded, similar investment efforts generated less output growth than before when investments were in more mature and labour-intensive technologies.

Figure 2 Capital-Output Ratios in 1990 US$, Total Economy South-Korea, Taiwan and USA, 1963-1996



Source: see Tables 5 and 6

Figure 3 Capital-Output Ratios in 1990 US$, Manufacturing, South-Korea, Taiwan and USA, 1963-1996



Source: see Tables 5 and 6

The remaining potential for catch up

To fully assess the impact on the growth potential of the Korean and Taiwanese economy we need to look not only at the relation between capital and output, but also take labour input into account. Initially, investments were coupled with a rapid increase in the labour force, but during the 1980s the growth of the labour force stagnated, especially in manufacturing.

Table 5 shows the non-residential capital stock per hour worked in South Korea, Taiwan and the United States. The table confirms the extraordinary rapid growth of capital intensity in Korea and Taiwan, in particular since the early 1970s both in manufacturing and the total economy. Before 1973 capital intensity grew more slowly in particular in Korea. However, it should be recognised that in 1963 Korean capital intensity in manufacturing was already 50 per cent higher than in Taiwan (see also above). Despite the rapid growth in capital-labour ratios, the gap in capital intensity relative to the United States was still huge by 1993. For the total economy capital-labour ratios were around 25 per cent of the US level in 1993. For manufacturing relative capital intensity was somewhat higher but still left a gap of about 60 per cent in both countries compared to the United States.[18] This indicates that also within manufacturing, relative labour intensive activities still dominate production. This is also true at a lower level of aggregation. Timmer (1999) found large gaps in capital intensity between the East-Asian countries and the USA in all 2-digit manufacturing industries, except textiles.

To analyse the issue of diminishing returns comprehensively, we need to look not only at the capital-labour ratios but also at the labour productivity ratios relative to the United States. Table 6 shows the level of value added per hour worked in South Korea, Taiwan and the United States for the total economy and manufacturing. It is clear that the rapid growth in capital intensity is reflected in rapid labour productivity growth. It appears that despite the lower level of capital intensity for the total economy, the labour productivity level for the total economy has been substantially higher than in manufacturing. This implies that non-manufacturing sectors create higher productivity levels with lower capital intensity. This again points at the different relative output price levels in manufacturing and non-manufacturing sectors dicussed above. Even though in domestic prices manufacturing tends to create more output per working hour with more capital per working hour, in international prices, non-manufacturing sectors create more output per working hour even with less capital.

Figures 4 and 5 show the relation between the non-residential capital stock per hour worked and GDP per hour worked in 1990$ for the total economy and manufacturing respectively in a graphical format. The figures clearly show the rapid catching up with the USA but also indicate the remaining potential for further growth in East Asia through narrowing the two mentioned gaps: one through increased capital intensity and another one through a rise in

[18] The levels of capital intensity in South Korean manufacturing differ substantially from those presented in Timmer (1999). This is due to the differences in the labour series used. Here we used employment series from the national accounts which are about 50 per cent higher than those found in the manufacturing census which were used by Timmer (1999). Further investigation into these differences is warranted.

productivity. For the total economy the gap in capital intensity is especially large. In manufacturing the gap in labour productivity seems to be relatively large. With the same amount of capital per hour worked, the United States generated much more output in the 1960s than the East-Asian countries in the 1990s. The concave nature of the growth paths indicates an increasing capital-output ratio with diminishing returns as in the traditional growth model of Solow (1956).

Table 5: Capital per Hour Worked in Total Economy and Manufacturing, 1963-1993, South Korea, Taiwan and USA, in 1990 US$ and average per cent growth rate

	South Korea		Taiwan		United States	
	Total Economy	Manufac-Turing	Total Economy	Manufac-turing	Total Economy	Manufac-Turing
	1990 US$		1990 US$		1990 US$	
1963	1.19	2.73	1.37	1.80	41.31	25.17
1973	2.63	3.29	3.43	4.39	49.92	33.13
1985	8.90	9.96	10.68	11.33	63.54	51.01
1996	20.06	33.48	23.00	30.19	69.94	65.42
	average (%) growth-rate		average (%) growth-rate		average (%) growth-rate	
1963-73	7.9	1.9	9.2	8.9	1.9	2.7
1973-85	10.2	9.2	9.5	7.9	2.0	3.6
1983-96	7.4	11.0	7.0	8.9	1.0	2.3

Source: Capital stock from Tables 2 and 3. Converted to 1990 US$ on the basis of purchasing power parities for investment calculated from Penn World Tables, Version 5.6. Employment from national accounts: South Korea from EPB, *Annual Report on the Economically Active Population*; Taiwan from DGBAS, *Statistical Yearbook of the Republic of China* and *Monthly Bulletin of Manpower Statistics.* United States from BEA, *National Income and Product Accounts of the United States*. Working hours for total economy from GGDC Total Economy Database and for manufacturing from Pilat (1994) for Korea and USA, and from DGBAS, *Monthly Bulletin of Earnings and Productivity* for Taiwan.

Table 6: Value Added (at factor cost) per Hour Worked in Total Economy and Manufacturing, 1963-1993, South Korea, Taiwan and USA, in 1990 US$ and average per cent growth rate

	South Korea		Taiwan		United States	
	Total Economy	Manufac-Turing	Total Economy	Manufac-turing	Total Economy	Manufac-Turing
	1990 US$		1990 US$		1990 US$	
1963	2.24	0.83	1.90	1.23	18.52	14.19
1973	3.56	1.76	3.89	2.85	23.60	19.10
1985	6.07	3.56	7.45	5.00	27.33	24.19
1996	10.34	8.46	14.12	9.78	30.64	32.91
	average (%) growth-rate		average (%) growth-rate		average (%) growth-rate	
1963-73	4.7	7.6	7.2	8.4	2.4	3.0
1973-85	4.4	5.8	5.4	4.7	1.2	2.0
1983-96	4.8	7.9	5.8	6.1	1.0	2.8

Source: Output from Bank of Korea, *National Income in Korea 1975*, and *National Accounts*, various issues linked with OECD, *National Account Statistics, 1997*.; Taiwan from DGBAS, *National Income in Taiwan Area of the Republic of China, 1994;* United States from BEA, *National Income and Product Accounts of the United States*. Converted to 1990 US$ on the basis of 1990 Geary Khamis purchasing power parities from Maddison (1995) for total economy. For manufacturing on the basis of unit value ratios from Pilat (1994) for South Korea and from Timmer (1999) for Taiwan. Employment and hours as for Table 5.

Figure 4 Labour Productivity and Capital Intensity, Total Economy, 1990 US$

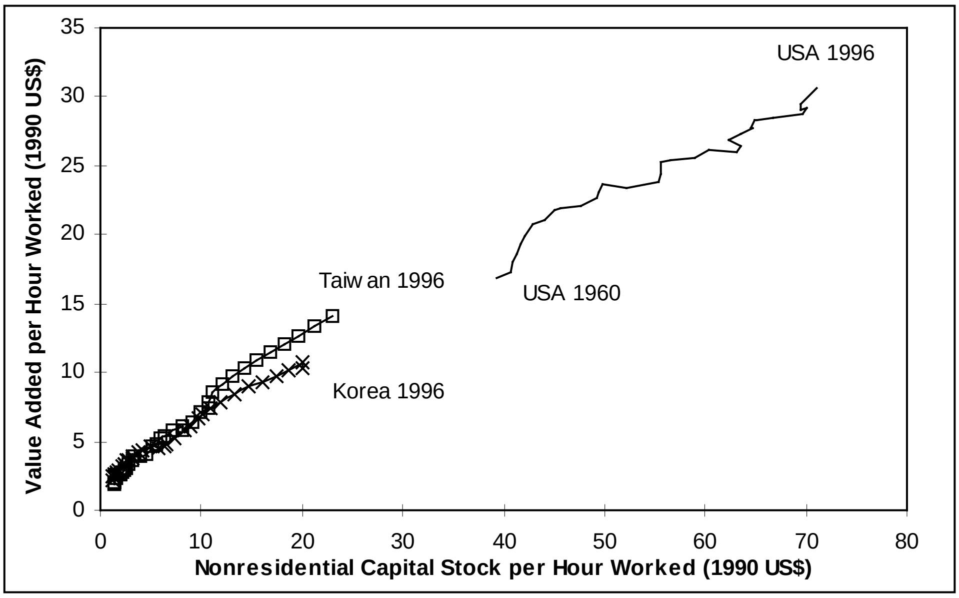
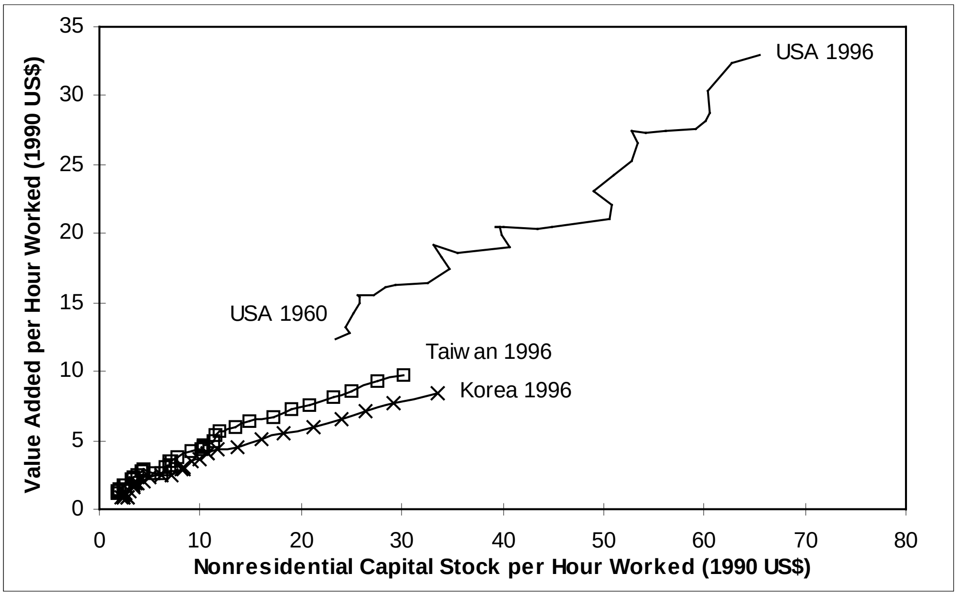


Figure 5 Labour Productivity and Capital Intensity, Manufacturing, 1990 US$



Nevertheless despite the rise in capital intensity, the findings suggest that continued growth in East Asia on the basis of expansion of inputs is not 'inevitably subject to diminishing returns' (Krugman, 1994, p.63). There remains substantial scope for further investment, but it must be accompanied with measures that help to realise the potential of productivity improvements through disembodied technical change.

TFP growth in the previous decades might have been positive as found above, but the East Asian countries apparently started to grow from rather low relative levels of productivity and gaps with the USA still remain. The finding that gaps in capital intensity between the US and the East-Asian countries are still large suggests that there is still ample scope for further investment-driven growth, i.e. realising the remaining catch-up potential. At the same time, there is further catch up potential through improvements in productivity levels which, although they grew rapidly in the previous decades, are still far lagging behind the US levels.

5. Conclusions

In this paper we first reconstructed the non-residential capital stock of South Korea and Taiwan based on long-term series of investment in non-residential buildings and machinery and equipment. Secondly, we looked at the impact of various capital input measures on total factor productivity growth. Finally, to assess the potential for continued catch-up of the emerging economies towards productivity levels of the more advanced countries, we analysed capital-output ratios and the change comparative levels of capital intensity and labour productivity.

For both countries we find a rapid growth of the capital stock for the total economy and for manufacturing, with growth rates that peaked between the mid-1960s and the mid-1980s. In terms of capital per hour worked, the growth trend has continued to accelerate since the mid 1980s as employment growth slowed down. In particular with capital inputs measured in terms of service flows, total factor productivity growth is low up to the mid 1980s, but since then shows some improvement. With respect to the capital-output ratios we find a continuous rise over time for the total economy, and for manufacturing we found a strong rise in capital-output ratios in particular since the 1980s. At the same time there are still large gaps between the two East Asian countries and the USA in terms of capital-labour ratios and labour productivity. This indicates that despite the diminishing returns to capital goods, especially in manufacturing, opportunities for further growth on basis of accumulation are still far from exhausted.

Given the rise in capital-output ratios, the remaining catch-up potential needs to be realised by complementing capital accumulation with changes in the industrial stucture, introduction of new technologies and improvements in credit allocation mechanisms. This need is reinforced by the effects of the currency crisis in 1997 and 1998. Among other things, foreign direct investment can also play an important role in this process by augmenting the domestic investment effort and through associated technology spillovers.

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Appendix Table 1.1 Nonresidential Gross Fixed Capital Formation and Nonresidential Gross Fixed Capital Stock in South Korea, Total Economy

	Gross Fixed Capital Formation (GFCF), bln. 1990 Won			Gross Fixed Capital Stock (GFCS), mln. 1990 Won			GFCS in 1990
	Structures	Equipment	Total	Structures	Equipment	Total	mln. US$
1914	129						
1915	110						
1916	118						
1917	146						
1918	188						
1919	174						
1920	134						
1921	152						
1922	180						
1923	183						
1924	147						
1925	130						
1926	189						
1927	260						
1928	303						
1929	330						
1930	327						
1931	258						
1932	304						
1933	327						
1934	427						
1935	560						
1936	740						
1937	688						
1938	833						
1939	580	475	1055				
1940	650	532	1182				
1941	659	539	1198				
1942	655	536	1191				
1943	665	544	1209				
1944	636	520	1156				
1945	0	0	0				
1946	0	0	0				
1947	186	152	338				
1948	200	164	364				
1949	215	176	391				
1950	231	189	421				
1951	0	0	0				
1952	0	0	0				
1953	266	88	354	7304	2198	9502	14620
1954	280	125	405	7505	2003	9508	14630
1955	369	158	527	7762	1823	9584	14747
1956	317	218	535	8025	1688	9714	14947
1957	420	231	651	8294	1589	9883	15206
1958	432	212	644	8611	1491	10102	15544
1959	497	189	686	8983	1536	10519	16185
1960	415	217	632	9354	1738	11092	17067
1961	523	229	752	9723	1916	11639	17908
1962	706	303	1009	10228	2088	12316	18951

1963	887	399	1286	10926	2337	13263	20407
1964	861	306	1167	11717	2579	14296	21998
1965	1135	379	1514	12620	2865	15484	23826
1966	1400	802	2203	13753	3455	17208	26478
1967	1640	1059	2699	15104	4342	19446	29921
1968	2303	1384	3687	16886	5457	22343	34378
1969	3272	1678	4950	19476	6846	26323	40502
1970	3309	1604	4913	22591	8299	30891	47531
1971	3197	1974	5171	25676	9864	35540	54685
1972	3304	2199	5503	28737	11729	40466	62264
1973	4178	2652	6830	32251	13954	46205	71095
1974	3968	3181	7149	36028	16667	52695	81082
1975	4443	3484	7927	39843	19777	59620	91737
1976	5307	4717	10024	44289	23611	67901	104478
1977	6616	6312	12928	49794	28775	78570	120894
1978	7789	9387	17176	56573	36273	92846	142861
1979	8846	10875	19720	64521	46061	110583	170153
1980	8725	8859	17584	72914	55338	128252	197340
1981	8639	8900	17539	81202	63287	144488	222323
1982	9977	8937	18914	90113	70984	161097	247880
1983	11936	9695	21631	100680	78769	179448	276116
1984	13497	11312	24808	113205	87631	200836	309025
1985	14225	11860	26085	127066	97428	224494	345427
1986	13934	14677	28611	141090	108609	249699	384210
1987	16467	17483	33950	156175	122264	278438	428431
1988	18301	19766	38067	173434	137971	311406	479158
1989	21147	22567	43713	193024	155805	348829	536741
1990	25028	26845	51873	216042	176410	392452	603863
1991	28284	30088	58372	242698	199361	442059	680193
1992	29102	29767	58868	271257	221439	492696	758109
1993	31419	29722	61140	301244	241052	542297	834428
1994	33650	36726	70376	333454	264409	597863	919929
1995	36613	42521	79134	368243	295153	663396	1020762
1996	39917	46094	86013	406140	330541	736682	

Sources and notes: Total gross capital formation (excluding residential and land improvement) for 1914-1938 Mizoguchi and Umemura (1988), and for 1953-1996 from Bank of Korea, *National Accounts* (various issues). Capital formation from 1938-1953 on the basis of output series assuming investment-output ratios at 0.10 for the period 1939-1944, at 0.00 for 1945 and 1946, at 0.05 for 1947-1950 and at 0.00 for 1951 and 1952. Output from A. Maddison (1995), *Monitoring the World Economy, 1820-1992* (OECD Development Centre). After linking, the whole investment series was expressed in 1990 Won. Pre-1953 figures were divided into series for nonresidential structures and machinery and equipment on the basis of shares derived from Japanese investment figures (from Maddison, 1995) which we lagged about 20 years, i.e. 65 per cent for structures between 1914 and 1920, 60 per cent for structures between 1921 and 1930 and 55 per cent between 1931 and 1952. Moreover we discounted all pre-1953 investment by 40 per cent for war damage (Maddison, 1998, Table 3.10, p. 66).Investment was accumulated by using the standardized asset lives of 39 years for structures and 14 years for equipment from Maddison (1995). Stocks adjusted to mid-year. Estimates were converted to US dollars on the basis of PPPs for investment obtained from Penn World Tables 5.3 (see Summers and Heston, 1991).

Appendix Table 1.2 Nonresidential Gross Fixed Capital Formation and Nonresidential Gross Fixed Capital Stock in Taiwan, Total Economy

	Gross Fixed Capital Formation (GFCF), mln. 1991 Taiw. $			Gross Fixed Capital Stock (GFCS), mln. 1991 Taiw. $			GFCS in 1990 mln. US$
	Structures	Equipment	Total	Structures	Equipment	Total	
1912	2736						
1913	2213						
1914	1840						
1915	1523						
1916	1541						
1917	2709						
1918	2242						
1919	3389						
1920	5059						
1921	4333						
1922	3455						
1923	3503						
1924	2839						
1925	3900						
1926	3987						
1927	4720						
1928	5736						
1929	6053						
1930	5535						
1931	4826						
1932	5789						
1933	6401						
1934	7194						
1935	9250						
1936	9903						
1937	7856	6428	14284				
1938	8649	7077	15726				
1939	9886	8089	17975				
1940	9850	8059	17909				
1941	10836	8866	19702				
1942	11633	9518	21151				
1943	7930	6489	14419				
1944	5446	4456	9902				
1945	0	0	0				
1946	0	0	0				
1947	3454	2826	6280				
1948	3738	3058	6796				
1949	4047	3311	7357				
1950	4380	3584	7964				
1951	7792	2787	10579	128352	47632	175984	6528
1952	9321	4168	13489	135423	47059	182482	6769
1953	12351	4986	17337	145043	47086	192129	7139
1954	12825	4897	17722	156622	47183	203806	7573
1955	11044	4322	15366	167638	46715	214353	7964
1956	11671	5946	17617	177720	46334	224054	8325
1957	10703	6372	17075	187422	47691	235113	8736
1958	13127	7744	20871	197648	51465	249113	9256
1959	15843	9388	25231	209598	58695	268293	9969
1960	19749	10355	30104	224577	68566	293143	10892

1961	20278	12242	32520	242254	78452	320706	11916
1962	23638	11329	34967	262125	87295	349420	12983
1963	26515	13008	39523	285299	96279	381578	14178
1964	30073	14974	45047	311571	106823	418394	15546
1965	31304	22995	54299	339893	122622	462515	17185
1966	36547	30824	67371	371207	146054	517261	19219
1967	44081	38318	82399	408384	176048	584432	21715
1968	52291	45986	98277	453033	213259	666292	24757
1969	56011	55132	111143	503708	259208	762916	28347
1970	56496	72503	128999	556853	317892	874744	32502
1971	59656	92513	152169	611744	394241	1005985	37378
1972	72219	110350	182569	674025	488614	1162639	43199
1973	75009	127148	202157	743560	598797	1342357	49877
1974	84038	148810	232848	818151	726905	1545055	57408
1975	120389	160979	281368	914618	870501	1785119	66328
1976	131862	157433	289295	1035416	1017921	2053337	76294
1977	150848	145160	296008	1171820	1157049	2328869	86531
1978	163419	167028	330447	1323392	1299152	2622544	97443
1979	173923	204165	378088	1486143	1465764	2951907	109681
1980	187713	251767	439480	1660755	1666821	3327575	123639
1981	184362	270769	455131	1840051	1893518	3733569	138724
1982	189111	269476	458587	2020919	2121488	4142407	153915
1983	185251	267302	452553	2204087	2339318	4543405	168815
1984	197364	267440	464804	2393760	2542872	4936632	183425
1985	207329	230077	437406	2596107	2709122	5305229	197121
1986	233927	261790	495717	2815008	2853624	5668632	210623
1987	254318	329511	583829	3055535	3030526	6086060	226133
1988	286300	384699	670999	3321952	3249652	6571603	244174
1989	313447	461939	775386	3617612	3518076	7135688	265133
1990	358767	501870	860637	3947633	3840775	7788407	289386
1991	423599	524055	947654	4330259	4202441	8532700	317041
1992	462473	607989	1070462	4762459	4612369	9374828	348331
1993	512689	626672	1139361	5237452	5044103	10281555	382021
1994	569017	654288	1223305	5766371	5456617	11222987	417001
1995	599281	719587	1318868	6339162	5882286	12221448	454100
1996	608070	774021	1216139	6931650	6358968	13290618	493826

Sources and notes: Total gross capital formation (excluding residential and land improvement) for 1912-1938 Mizoguchi (1997), and for 1951-1995 from DGBAS, *National Income in the Taiwan Area of the Republic of China* (various issues). Capital formation from 1938-1951 on the basis of output series assuming investment-output ratios at 0.10 for the period 1939-1944, at 0.00 for 1945 and 1946 and 0.05 for 1947-1950. Output from A. Maddison (1995), *Monitoring the World Economy, 1820-1992* (OECD Development Centre). After linking, the whole investment series was expressed in 1991 Taiwanese dollars. Pre-1951 figures were divided into series for nonresidential structures and machinery and equipment on the basis of shares derived from Japanese investment figures (from Maddison, 1995) which we lagged about 20 years, i.e. 65 per cent for structures between 1914 and 1920, 60 per cent for structures between 1921 and 1930 and 55 per cent between 1931 and 1952. Investment was accumulated by using the standardized asset lives of 39 years for structures and 14 years for equipment from Maddison (1995). Moreover we discounted all pre-1951 investment by 40 per cent for war damage (Maddison, 1998, Table 3.10, p. 66). Stocks adjusted to mid-year. Estimates were converted to US dollars on the basis of PPPs for investment obtained from Penn World Tables 5.3 (see Summers and Heston, 1991).

Appendix Table 1.3 Nonresidential Gross Fixed Capital Formation and Nonresidential Gross Fixed Capital Stock in South Korea and Taiwan, Manufacturing

	South Korea			Taiwan		
	GFCF in 1990 bln. Won	GFCS in 1990 bln. Won	GFCS in 1990 mln. US$	GFCF in 1991 mln. T. $	GFCS in 1991 mln. T. $	GFCS in 1990 mln. US$
1935				3345		
1936				3581		
1937				2841		
1938				3128		
1939	144			3575		
1940	161			3562		
1941	164			3918		
1942	163			4207		
1943	165			2868		
1944	158			1969		
1945	0			0		
1946	0			0		
1947	46			1249		
1948	50			1352		
1949	53			1463		
1950	57			1584		
1951	0			2104		
1952	0			2209		
1953	81			3760		
1954	81			4083		
1955	143			2434		
1956	181			3699		
1957	196			4079		
1958	185			4667		
1959	153			4762		
1960	163			6537		
1961	162			6853		
1962	217			6677		
1963	283	3005	4643	7943	77514	2,880
1964	279	3141	4852	12498	87867	3,265
1965	385	3364	5197	15144	100874	3,748
1966	656	3857	5958	19069	117592	4,369
1967	652	4346	6714	28999	144067	5,353
1968	875	5056	7810	34082	176428	6,555
1969	993	5891	9101	37386	212633	7,901
1970	821	6712	10370	48624	261257	9,707
1971	1062	7774	12010	51432	312689	11,618
1972	820	8548	13206	64697	376137	13,976
1973	1492	9991	15435	77820	452605	16,817
1974	1686	11624	17957	97851	548993	20,398
1975	2233	13799	21318	118325	665734	24,736
1976	3016	16815	25977	111002	774632	28,782
1977	4264	21079	32565	93332	865755	32,168
1978	5799	26797	41399	87114	949109	35,265
1979	6307	33024	51018	114742	1059768	39,377
1980	4497	37378	57745	143947	1201281	44,635
1981	4143	41341	63867	151978	1349560	50,144
1982	4295	45440	70200	128669	1474150	54,773

1983	4536	49791	76921	125661	1595144	59,269
1984	6158	55796	86199	159823	1750205	65,031
1985	7353	62985	97306	138157	1881825	69,921
1986	9084	71908	111090	187484	2062456	76,633
1987	12645	84335	130288	220953	2276732	84,594
1988	14418	98470	152125	243525	2512314	93,347
1989	16317	114507	176901	251988	2751804	102,246
1990	18932	133054	205554	252347	2989007	111,059
1991	19899	152296	235281	266761	3236699	120,263
1992	17618	169262	261492	294380	3502080	130,123
1993	16623	185010	285820	296212	3764210	139,863
1994	22022	206039	317030	334934	4061758	150,919
1995	27783	233000	358515	379819	4392953	163,224
1996	30239	262177	403409	417521	4759042	176,827

Sources and notes: Total gross capital formation (excluding residential and land improvement) for 1953-1993 (Korea) from Bank of Korea, *National Accounts* (various issues) and for 1951-1993 (Taiwan) from DGBAS, *National Income in the Taiwan Area of the Republic of China* (various issues). Pre-1953/1951 estimates of capital formation were obtained through linking with total economy series (see Appendix Tables 1.1 and 1.2). After linking, the whole investment series was expressed in 1990 bln. Won and 1991 mln. Taiwanese dollars. Investment was accumulated by using the standardized asset lives of 25 years for all nonresidential equipment, based on Van Ark and Pilat (1993). Moreover we discounted all pre-1951 investment by 40 per cent for war damage (Maddison, 1998, Table 3.10, p. 66). Estimates were converted to US dollars on the basis of PPPs for investment obtained from Penn World Tables 5.3 (see Summers and Heston, 1991).